HEAT EXCHANGER FOR COOLING AIR

CROSS REFERENCE TO RELATED APPLICATION

This application is based on Japanese Patent Application No. 2002-211218 filed on July 19, 2002, the disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to a heat exchanger having tubes and header tanks, which is suitable for an evaporator for a vapor compression refrigerant cycle system.

BACKGROUND OF THE INVENTION

An evaporator for a vapor compression refrigerant cycle system generally has a plurality of tubes and header tanks communicating with the tubes. The tubes are arranged vertically and the header tanks are connected to the top ends and bottom ends of the tubes. This kind of evaporator is for example disclosed in JP-A-2001-50686.

Incidentally, in a heat exchanger for cooling air, such as the evaporator, moisture condenses on surfaces of the tubes and fins, which are disposed between the tubes. In a case that the tubes are arranged vertically, the condensed water flows downwardly along the tube surfaces. Further, the condensed water is likely to accumulate around the lower position of the heat exchanger.

SUMMARY OF THE INVENTION

The present invention is made in view of the foregoing matter and it is an object of the present invention to provide a heat exchanger for cooling air with enhanced drainage of condensed water.

According to the present invention, a heat exchanger for cooling air includes tubes through which fluid flows, fins provided between tubes for increasing areas of heat-transfer surfaces, and a header tank. The tubes are arranged vertically and bottom ends of the tubes are connected to the header tank. The header tank is formed with drains, which are depressions, at positions between the tubes. The drains downwardly direct water that accumulates between the tubes.

Accordingly, condensed water, which flows downwardly and accumulates at lower positions of the tubes, drains away through the drains. Preferably, each of the depressions narrows toward its bottom, thereby facilitating drainage of the condensed water.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the present invention will become more apparent from the following detailed description made with reference to the accompanying drawings, in which like parts are designated by like reference numbers and in which:

Fig. 1A is a plan view of an evaporator according to the first embodiment of the present invention;

Fig. 1B is an end view of the evaporator according to the first embodiment of the present invention;

Fig. 2 is a cross-sectional view of a header tank of the evaporator according to the first embodiment of the present invention;

Fig. 3 is an enlarged perspective view of the lower side of the evaporator according to the first embodiment of the present invention;

Figs. 4A to 4C are explanatory views for explaining drainage of condensed water in the evaporator according to the first embodiment of the present invention;

Figs. 5A to 5C are schematic views for showing examples of shapes of drains formed on the evaporator according to the first embodiment of the present invention;

Fig. 6A is a perspective view of the lower side of an evaporator according to the second embodiment of the present invention;

Fig. 6B is a cross-sectional view of the lower side of the evaporator according to the second embodiment of the present invention;

Fig. 6C is a partial enlarged view of the evaporator shown in Fig. 6B;

Fig. 7 is a cross-sectional view of a header tank of an evaporator according to the third embodiment of the present invention;

Fig. 8 is a cross-sectional view of a header tank of an evaporator according to the fourth embodiment of the present

invention;

Fig. 9 is a cross-sectional view of a header tank of an evaporator according to the fifth embodiment of the present invention; and

Fig. 10 is a cross-sectional view of a header tank of an evaporator according to another modified embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

Embodiments of the present invention will be described with reference to drawings.

In the first embodiment, a heat exchanger for cooling air is employed to an evaporator of a vapor compression refrigerant cycle system. As shown in Figs. 1A and 1B, the evaporator 1 includes a plurality of flat tubes 2 through which refrigerant flows, corrugated fins 3 and header tanks 4.

The corrugated fins 3 are joined to outer surfaces of the tubes 2 for increasing areas of heat-transfer surfaces. The tubes 2 are arranged vertically. The header tanks 4 are connected to top and bottom ends of the tubes 2.

The tubes 2 and the fins 3 are alternately stacked and construct a core portion for performing heat exchange. In the embodiment, the evaporator 1 has two core portions. The core portions are arranged parallel with respect to an air flow direction, as shown in Figs. 1B and 2.

A connecting block 5 is joined to an end of one of the header tanks 4. The connecting block 5 connects the evaporator

1 to a box-type expansion valve, which includes a temperature sensor for detecting superheat of the refrigerant discharging from the evaporator 1 and an expansion valve for decompressing the refrigerant. An inlet port of the block 5 connects to an outlet side of the expansion valve. An outlet port 5b of the block 5 connects to an inlet side of the temperature sensor.

Each of the header tanks 4 is constructed by joining a core plate 4a into which tubes 2 are inserted and a tank plate 4b that forms a tank space through which the refrigerant flows. In this embodiment, each header tank 4 forms two tank spaces (air upstream side space and air downstream side space), as shown in Fig. 2.

The core plate 4a has a radius of curvature RC1 that is greater than a radius of curvature RC2 of the tank plate 4b, so the core plate 4a is flatter than the tank plate 4b. This is to increase a surface area of the core portion, that is, the length of the core portion exposed to the air, without an increase in an overall size of the evaporator 1.

As shown in Figs. 2 and 3, the header tank 4 is formed with drains 4c, which are depressions, at positions between the tubes 2. The drains 4c downwardly directs water that accumulates between the tubes 2.

Specifically, the bottom 4d of the drain 4c is sloped downward in a direction away from the tube 2, as shown in Fig. 2. Also, the drain 4c is formed such that it has substantially a diamond shape when viewed from the top, that is, viewed along the longitudinal direction of the tubes 2. (See Fig. 3)

The core plate 4a is pressed by a press die having a wedge shape, so that the drain 4c has substantially a V-shaped cross-section when viewed along the longitudinal direction of the bottom 4d. As shown in Fig. 4, the dimension (width) W3 of the drain 4c reduces toward the bottom 4d.

In the embodiment, the tubes 2, fins 3 and header tanks 4 are made of aluminum and integrally joined by brazing.

Next, advantageous effects of the embodiment will be described.

Because the tubes 2 are vertically arranged, condensed water flows downwardly along the surfaces of the tubes 2 and collects around the lower position of the core portion adjacent to the header tank 4. The water easily accumulates involved spaces where the fin 3 and the tube 2 are joined adjacent to the core plate 4a. In the embodiment, the drains 4c are formed in such involved spaces between the tubes 2. Therefore, the water drains away through the drains 4c.

According to LaPlace's equation (see, e.g. *Surface Tension*, Shu Ono, Kyoritsu Press.), an internal pressure P of the water accumulated in the V-shaped drain 4c and a radius R of curvature of the surface of the water have a following relationship.

$$P = -a/R + b$$

Here, "a" and "b" are proportionality constants. The right side of the equation has "-" sign because the pressure is lower than atmospheric pressure, that is, negative pressure.

According to the above equation, the smaller the radius R

of curvature of the surface of the water is, the lower the pressure P is. That is, the smaller the radius R of curvature is, the more the gap between a difference between the atmospheric pressure and the negative pressure increases.

When the water accumulates in the drain 4c to a predetermined amount as shown in Fig. 4A, it flows out of the drain 4c through a lowest end 4g (Fig. 3) of the drain 4c by its gravity force as shown in Fig. 4B. With this, the radius R of curvature of the water surface reduces from the state shown in Fig. 4A to the state shown in Fig. 4B ($R1 > R2$). Also, because the radius R (R2) reduces, the internal pressure P of the condensed water reduces ($P1 > P2$).

As a result, the water in the drain 4c draws water (water film) around the drain 4c into the drain 4c as shown by dotted arrows in Fig. 4C, so the radius R of curvature of the water surface increases again to the state shown in Fig. 4C.

Because draining and drawing of the water are repeated in the order shown in Figs. 4A, 4B, and 4C, the condensed water is effectively discharged.

Figs. 5A to 5C show examples of V-shapes of the drain 4c, the width of which reduces toward its bottom. In the embodiment, the V-shapes shown in Figs. 5A and 5B are preferable for the drains 4c. In Fig. 5A, the drain 4c is formed by curved walls 4e protruding inward. In Fig. 5B, the drain 4c is formed by flat walls 4f.

Since the drain 4c has substantially the diamond shape when viewed from the top, the lowest end 4g of the drain 4c is

in acute angle. Thus, the drain 4c has the substantially V-shaped cross-section also at its lowest position. Accordingly, the condensed water can continuously drain away.

The condensed water adheres to the surface of the fin 3 by surface tension. Therefore, it is preferable that a minimum distance Δ (Fig. 2) between the header tank 4 and the fin 3 in the vertical direction is in a range between equal to or greater than 0 mm and equal to or less than 1.0 mm, so that the condensed water adhering on the fins 3 can flow into the drain 4c by capillary action. Here, when the minimum distance Δ is 0 mm, the fin 3 contacts the header tank 4.

Since the ends of the tubes 2 are inserted in the header tank 4, a dimension (width) W1 of the tube 2 is smaller than a dimension (width) W2 of the header tank 4 minus two times thicknesses of the wall of the header tank 4, with respect to the air flow direction, as shown in Fig. 2. That is, the width W1 of the tube 2 is smaller than an inside width of the header tank 4. Further, the core plate 4a is substantially flat. In the evaporator having the above structure, the condensed water easily accumulates on the lower side header tank 4. In the embodiment, the condensed water is effectively drained away through the drains 4c of the header tank 4.

In the second embodiment, the evaporator 1 is provided with plates (drainage facilitating member) 6, as shown in Figs. 6A to 6C. The plate 6 is disposed such that a surface 6a opposes the header tank 4 and is spaced from the lowest end 4g of the drain 4c by a predetermined distance T.

The water reaches the lowest end 4g of the drain 4c and contacts the surface 6a. As a result, the water flows along the surface 6a as shown by a dotted arrow in Fig. 6C. Accordingly, the plates 6 facilitate drainage of water from the drains 4c. Preferably, the distance T is in a range between equal to or greater than 0 mm and equal to or less than 1.0 mm. The drainage-facilitating member 6 is not limited to the form of plate, as long as having the surface 6a.

In the third embodiment, the bottoms 4d of the drains 4c are sloped downwardly with respect to the air flow direction, as shown in Fig. 7. An air downstream position of the bottom 4d is lower than an air upstream position. Also in the third embodiment, the evaporator 1 provides advantages similar to those of the first embodiment.

In the fourth embodiment, the drains 4c are formed on the header tank 4 at the air upstream positions and the air downstream positions of the respective core portions, as shown in Fig. 8. Also in the fourth embodiment, the evaporator 1 provides advantages similar to those of the first embodiment.

In the fifth embodiment, the header tank 4 is integrally formed such as by extrusion and drawing, as shown in fig. 9. The drains 4c are formed in the manner similar to the first to the fourth embodiments. Thus, also in the fifth embodiment, the evaporator 1 provides advantages similar to those the above embodiments.

In the first embodiment, the single header tank 4 integrally forms two tank spaces therein. The first space is

for the air upstream side core portion and the second space is for the air downstream side core portion. However, the first and the second tank spaces can be provided by separate header tanks.

The cross-sections of the header tanks 4 are not limited to those of the above-described embodiments. For example, the header tank 4 can have a cross-section shown in Fig. 10.

The present invention is not limited to the evaporator, which cools air with latent heat of vaporization of the refrigerant. The present invention can be employed to a heat exchanger that cools air with sensible heat without changing phase of the refrigerant.

The present invention should not be limited to the disclosed embodiments, but may be implemented in other ways without departing from the spirit of the invention.